Principal Research Results

Electro-chemical Reduction of UO₂ Fuel and MOX Fuel

Background
Spent MOX fuel and spent high burn-up fuel are expected to be generated and, therefore, reprocessing technologies for these spent fuels are required in the near future. Also, discussion on fuel-cycle technologies to introduce fast reactors will be started after the operation of Rokkasho reprocessing plant begins. It will take at least several decades to replace all present light water reactors with fast reactors. Thus, flexibilities to correspond to the change of social needs will be one of the most important factors for the fuel-cycle technologies during the replacement period. (i) Low capital and running costs even in a small size plant. (ii) High ability to treat various kinds of spent fuels without major changes of process. (iii) High performance to resist nuclear proliferation.

Objectives
The aim of present study is to show the validity of the electro-chemical reduction process based on the experimental studies using 100g-scale of UO₂-fuel and 200mg-scale of MOX.

Principal Results

1. Electro-chemical reduction of UO₂ fuel
Fig.1 shows a schematic image of test cell and a picture of UO₂ fuel set on the Ti-cathode. Following results are obtained: (i) In LiCl solvent system, UO₂ fuel was completely reduced to U metal with 53% of current efficiency. Fig.2 shows the cross section of metal product. (ii) In CaCl₂ solvent system, UO₂ fuel was not completely reduced in the present test because the current efficiency was maintained at around 25%. However, the morphology of the product as given in Fig.3 showed that UO₂ fuel would be completely reduced if the operation continued. (iii) The morphology of the product was affected by the type of molten salt solvent, and the particle size and density of initial UO₂, as shown in Fig. 4. The adjustment of the product morphology could accelerate the process speed to be suitable for the industrial process.

2. Electro-chemical reduction of MOX fuel
In the MOX tests, (i) Both in LiCl and CaCl₂ solvent systems, MOX fuel containing Pu was completely reduced to metal. (ii) At the interface between the reduced and non-reduced regions, both regions formed a layer and a network structure in UO₂ fuel and in MOX fuel, respectively, as shown in Fig.5. Since the network structure could supply larger reaction area, the reduction of MOX fuel easily occurred in comparison to UO₂ fuel.

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Future Developments
Since the particle size and density of fuel is one of the most important parameters to control the process, optimization will be carried out. Also, the investigation of fuel-cycle scenario using the electro-chemical reduction process will be materialized.

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Reference
Fig. 2 Reduction product obtained in electro-chemical reduction test in LiCl.
(Grinded cross section shows metallic-shine.)

Fig. 3 Various reduced UO₂-particles obtained in electro-chemical reduction test in CaCl₂.
(White part : U-metal, grey part : U-oxide)

Fig. 4 Difference in reduction products obtained in LiCl and CaCl₂ systems.

Fig. 5 Interface between reduced (right) / non-reduced (left) regions

C. Harmonization of energy and environment

100g of UO₂ on cathode.

Fig. 1 Image of test cell.

Enlargement

LiCl system

The formation of porous structure progresses reduction reaction.

CaCl₂ system

In MOX fuel, a network structure was formed and it could increase the reaction surface.

Fig. 1 Image of test cell.